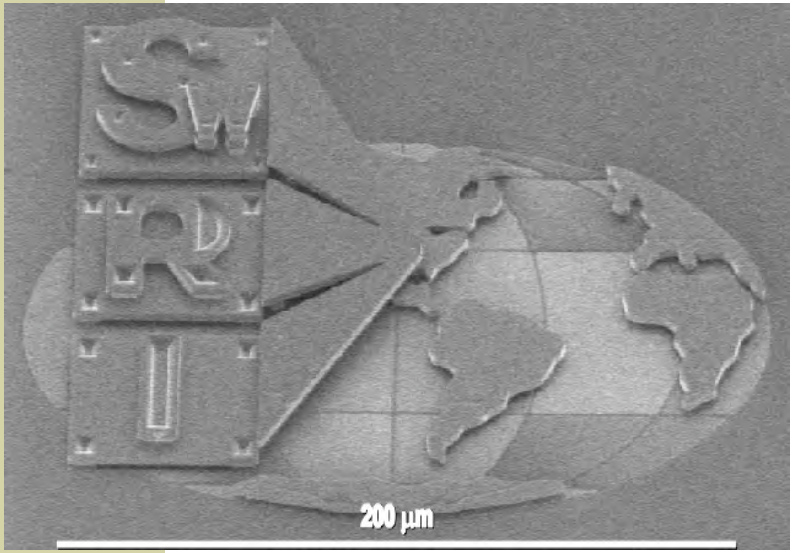

MEMPPS Micro-Electromechanical Planetary Probes

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Introduction

- Study describes the basic principles of Micro-Electromechanical Systems (MEMS) as basis for Micro-Electro-Mechanical Planetary Probes (MEMPPs)
- Technology applicable to broad array of planetary atmospheric and surface probes within very small packages and limited resources
- Focused observations in contrast to sophisticated assemblages of experiments and supporting systems
- MEMPPs provide several significant advantages
  - Integrated packages of intrinsically mechanically robust instrumentation and subsystems
  - Much smaller size, mass, and power requirements
  - May enable large numbers of distributed probes

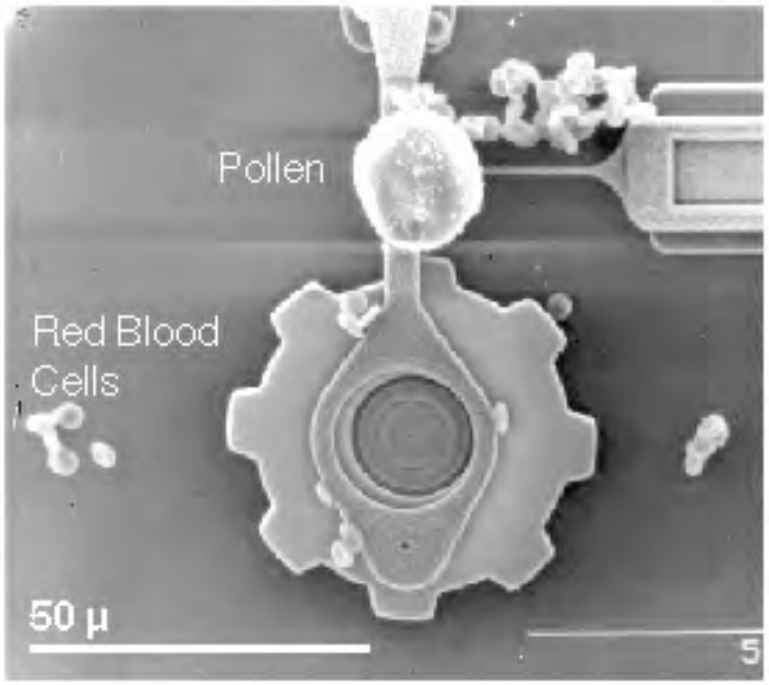
Outline

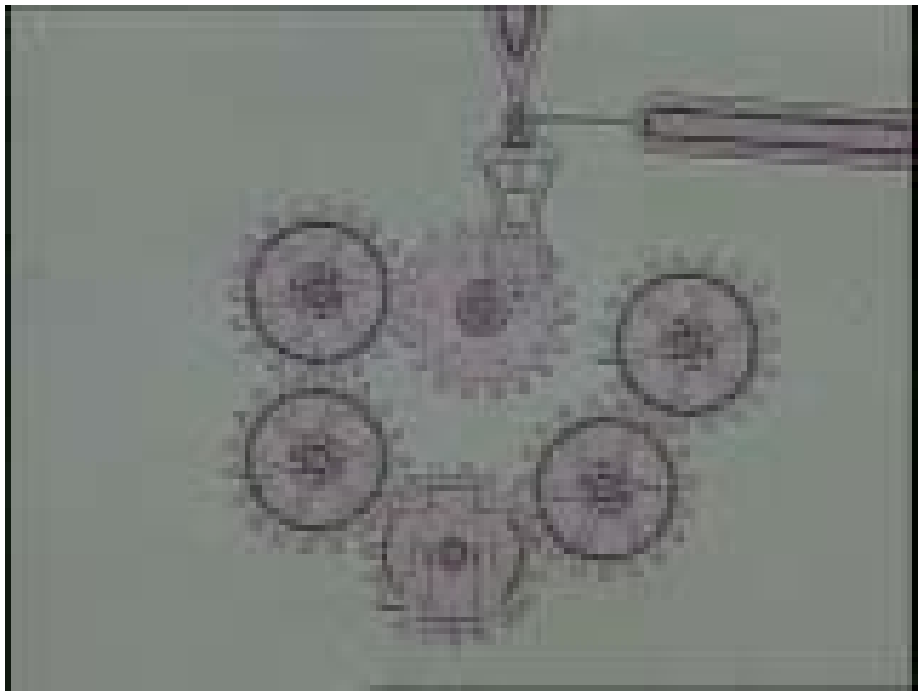
- What are MEMS?
- Environmental Considerations and Testing
- Applicability for Planetary Probes
- Conclusions

What are MEMS?

Micro-Electromechanical Systems

Micro-scale Mechanical Systems

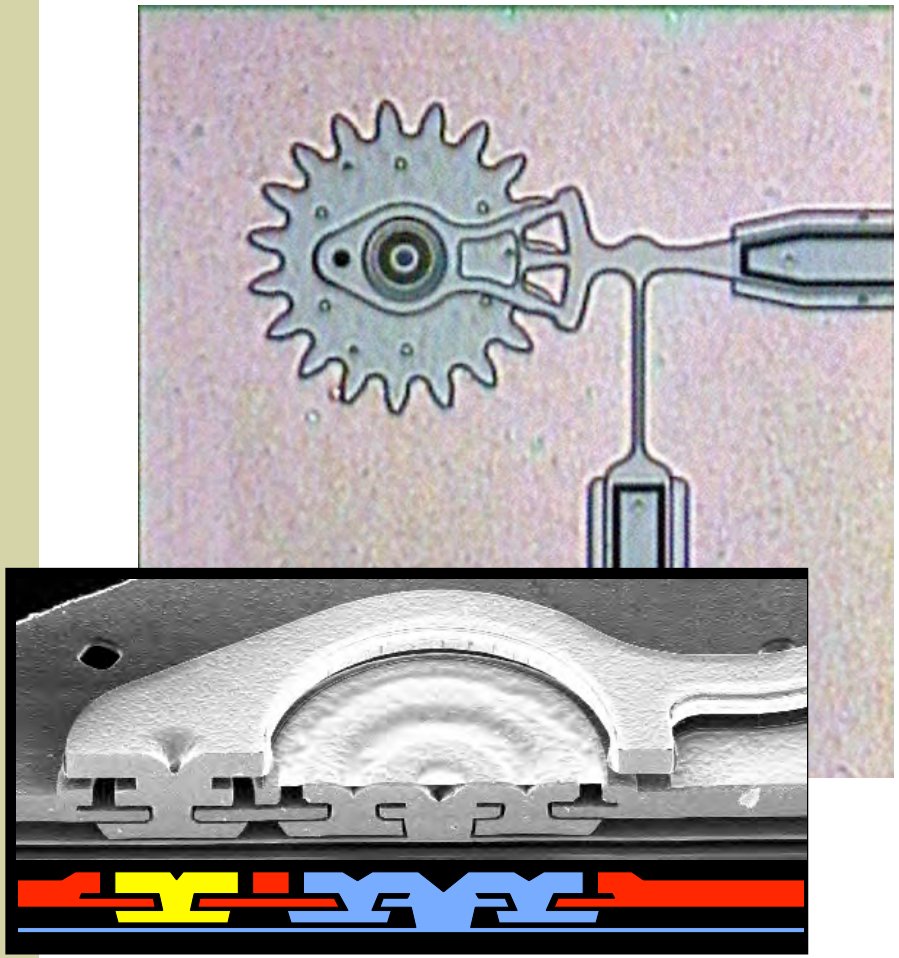




Images in this presentation courtesy Southwest Research Institute and Sandia National Laboratories.

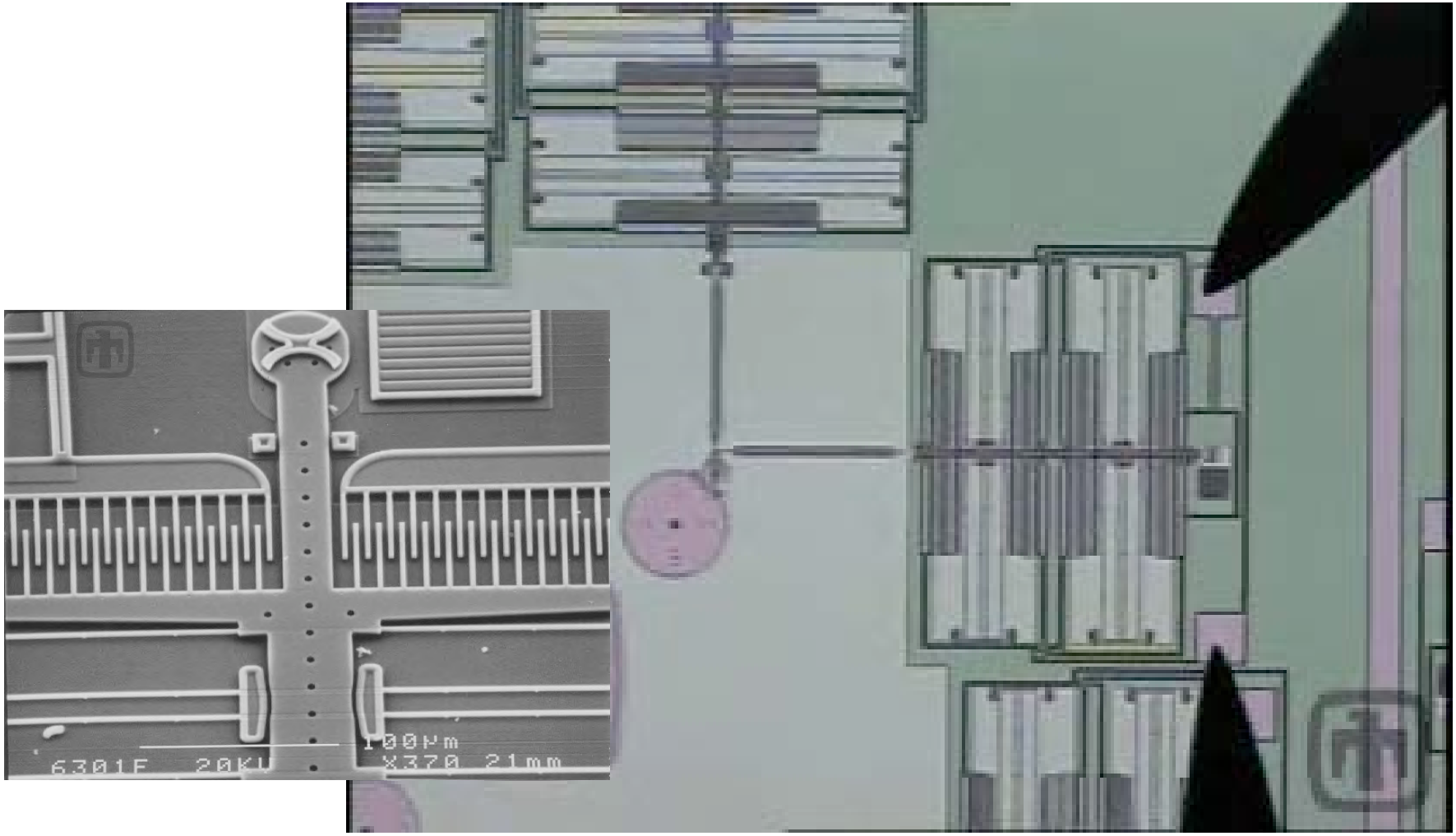
- Example: Two orthogonal linear drives linked to a rotary gear
  - > 350,000 RPM
  - Lifetime >7×10^9 revolutions w/ millions of start/stop cycles

How MEMS are built



- Micrometer scale machines built using same technology developed in the semi-conductor industry
  - Surface processes using photolithography, plating, etching and electro-mechanical planarization
  - Release from substrate w/o “stiction”
- Other processes: Deep Etches, LIGA, etc. also used

Electrostatic Actuation: Comb Drives

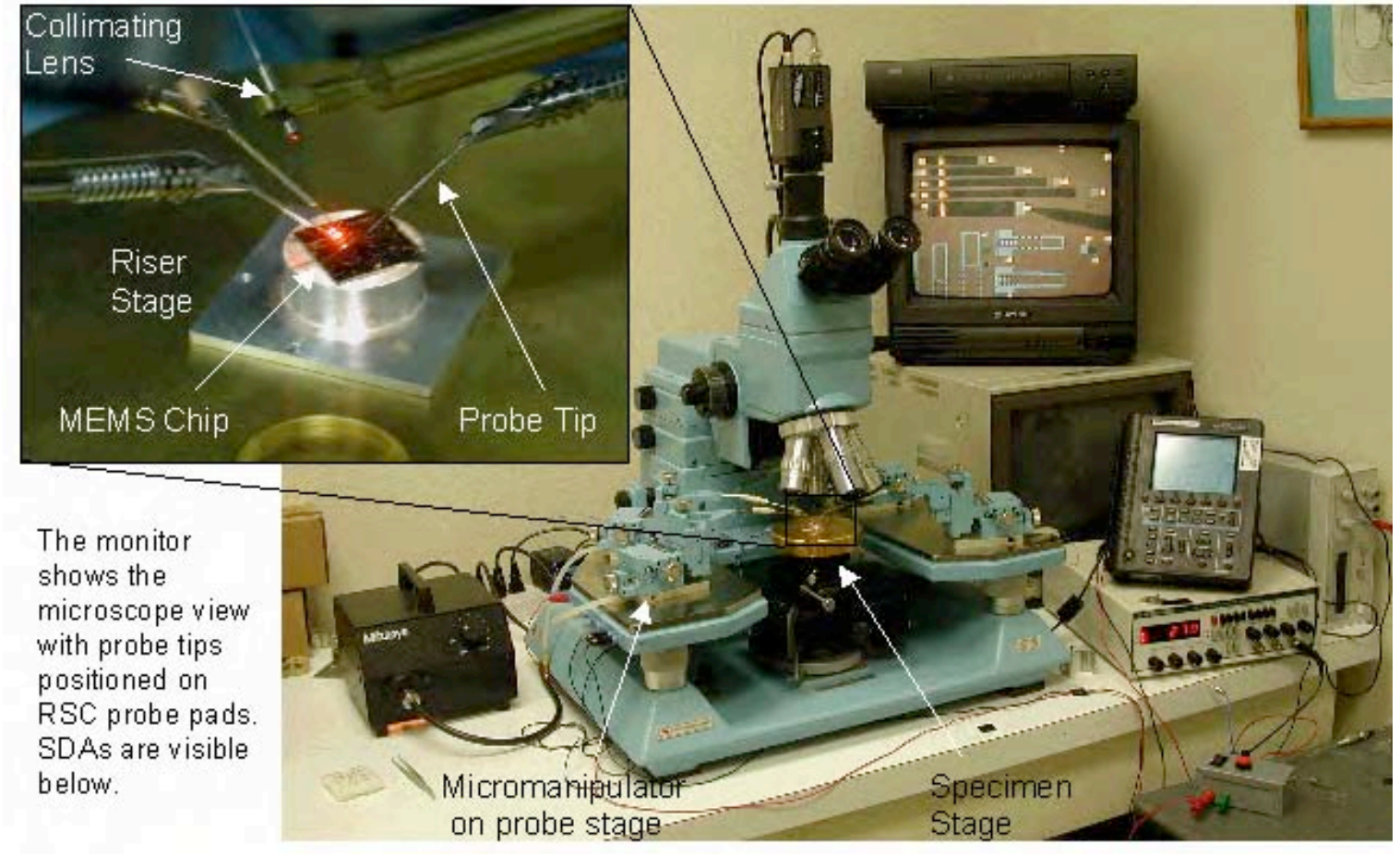


Environmental Considerations and Testing

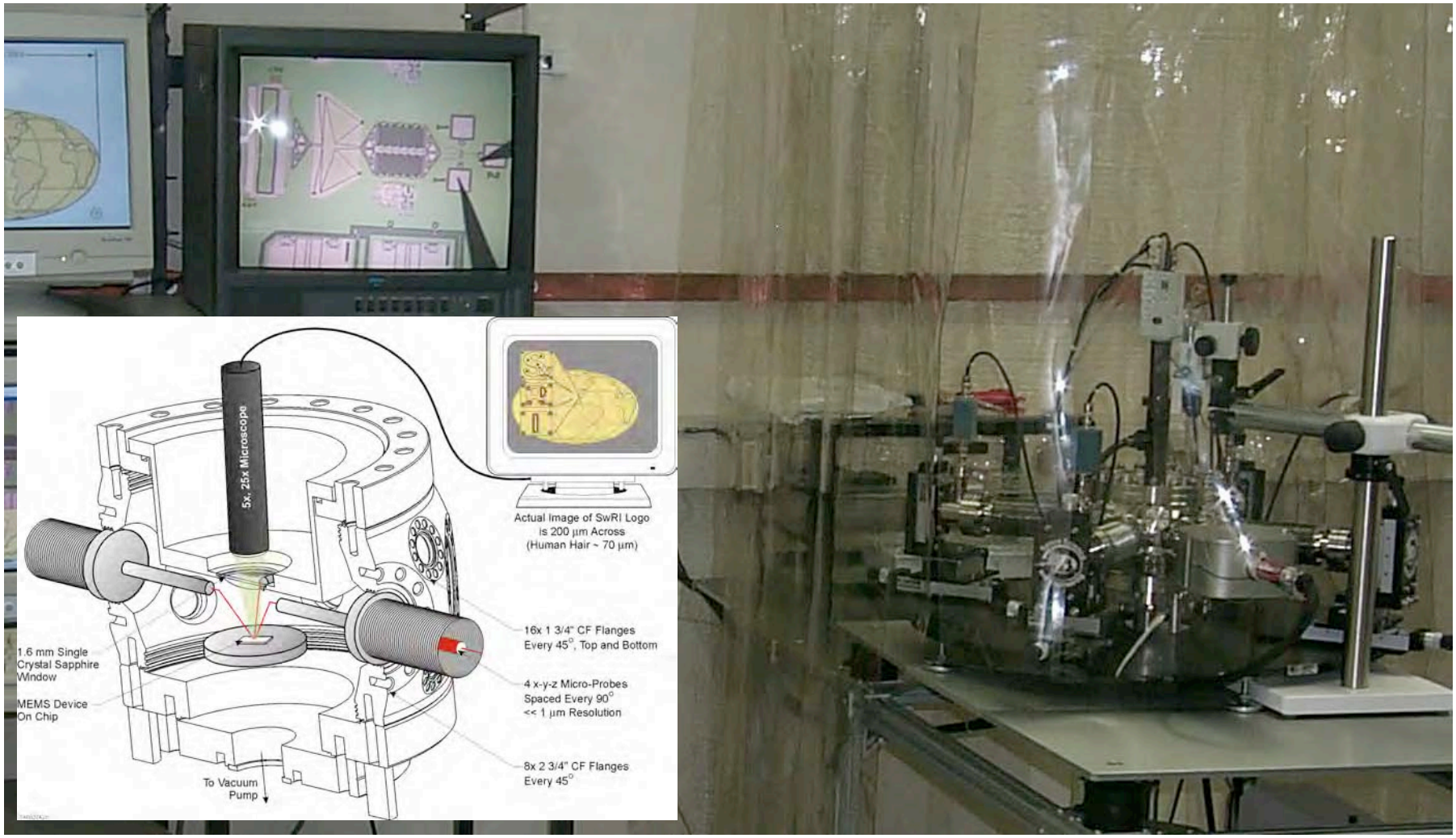
MEMS work and can be easily tested over very broad ranges of conditions

Micro-Probe Test Station

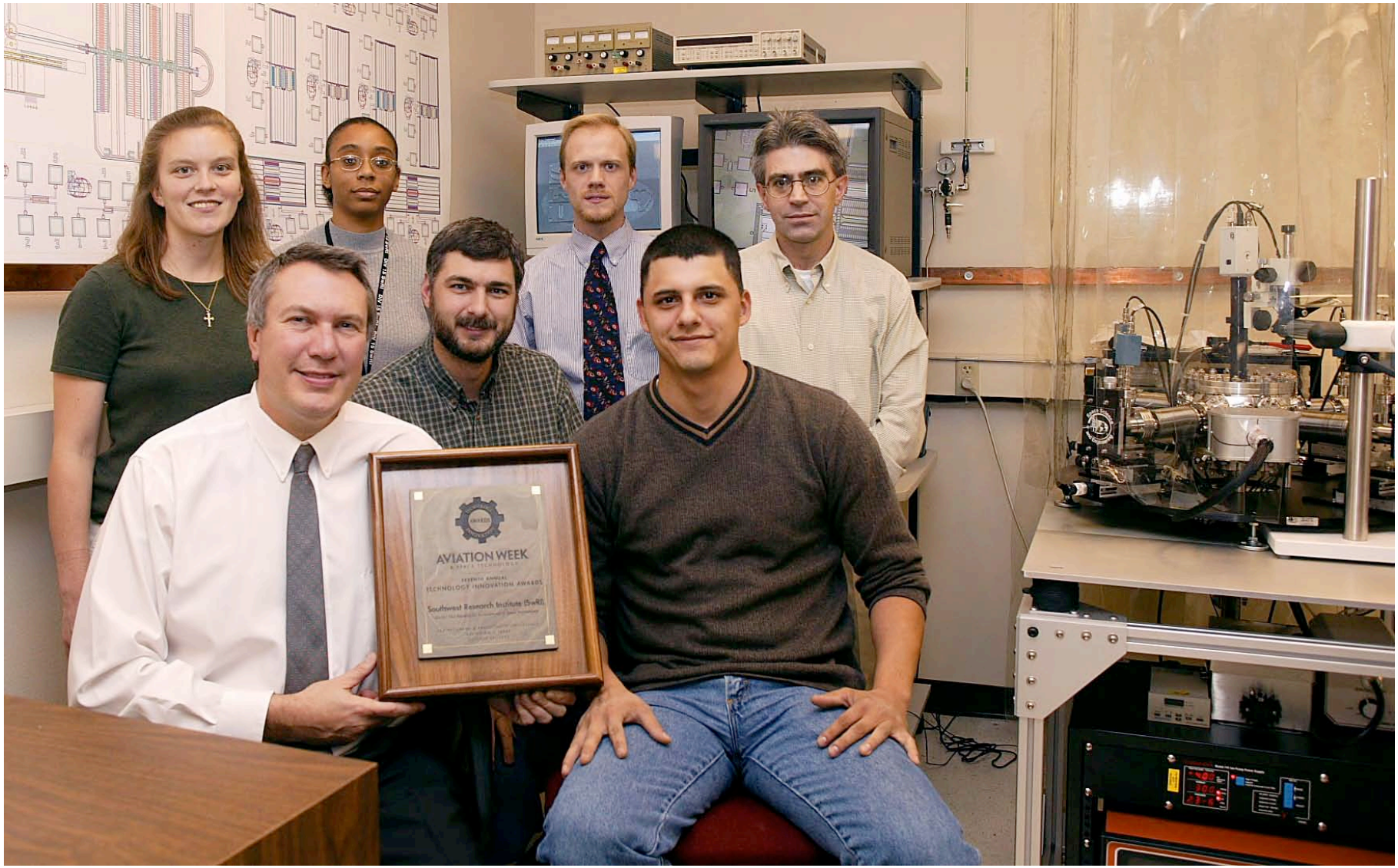
- Apply electrical signals
- Support optical elements
- Manipulate MEMS devices
- Operational imaging



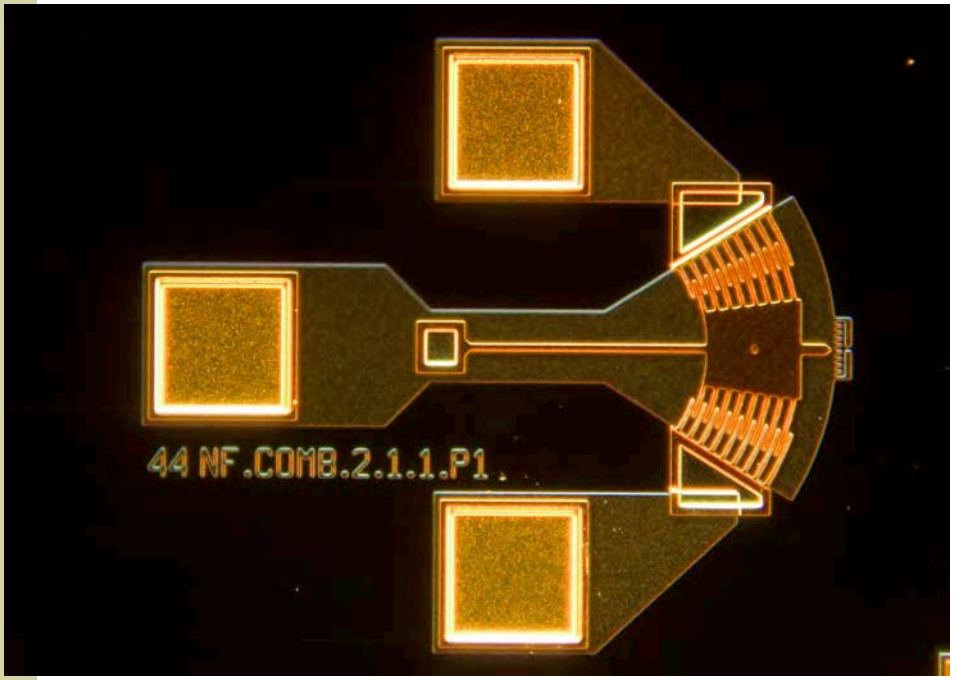
SwRI MEMS
Vacuum Micro-Probe Facility



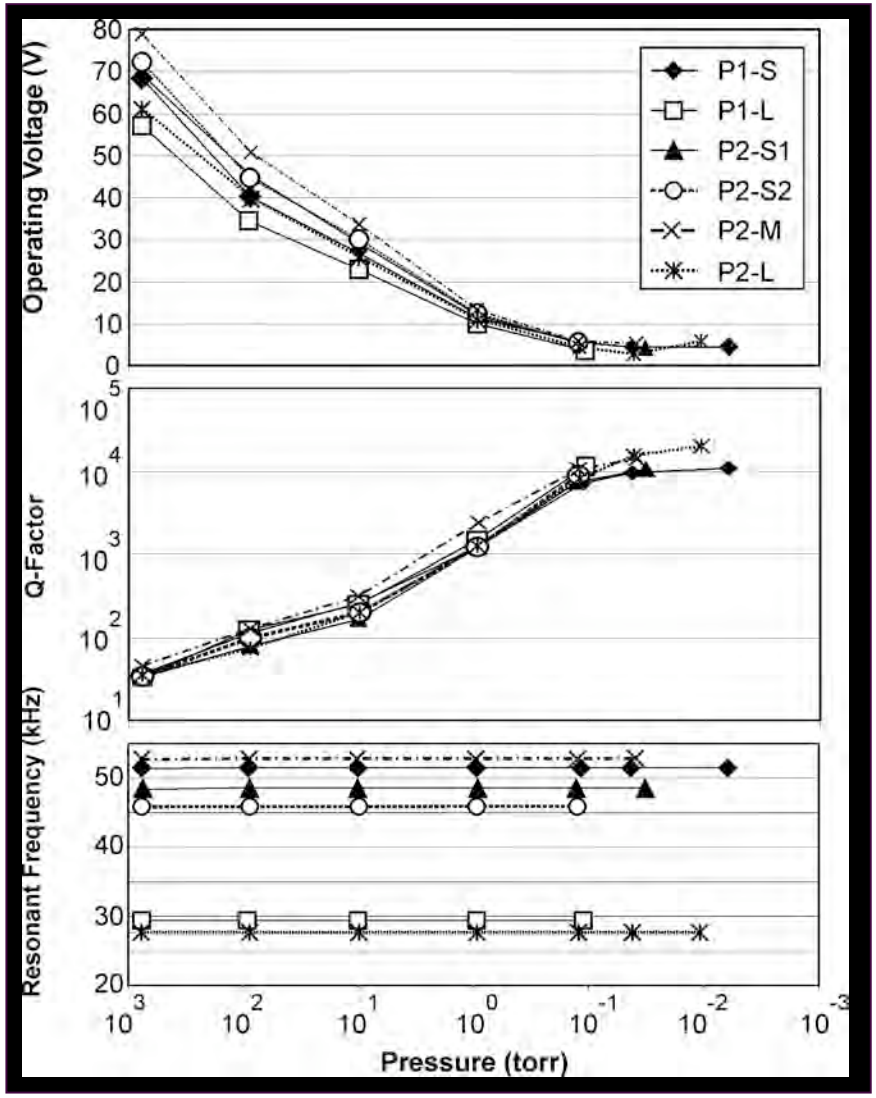
Aviation Week 2003
Technology Innovation Award



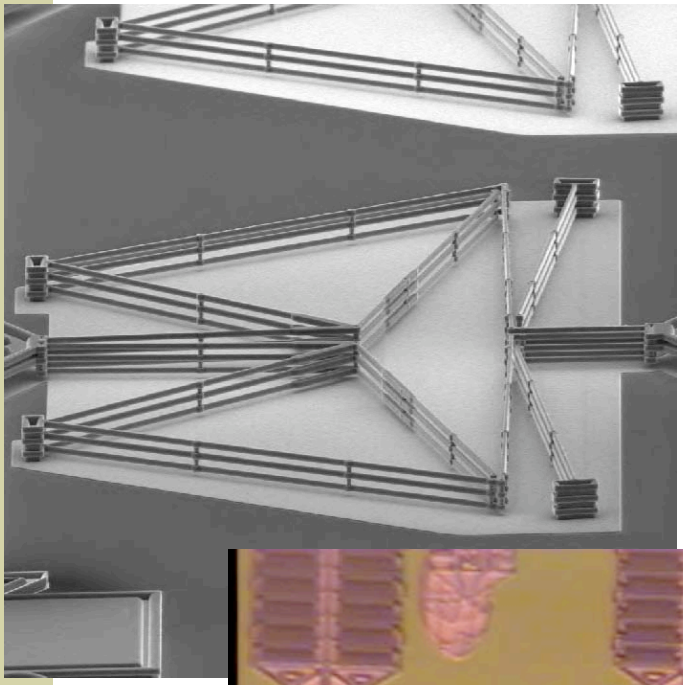
Example: Simple Oscillators

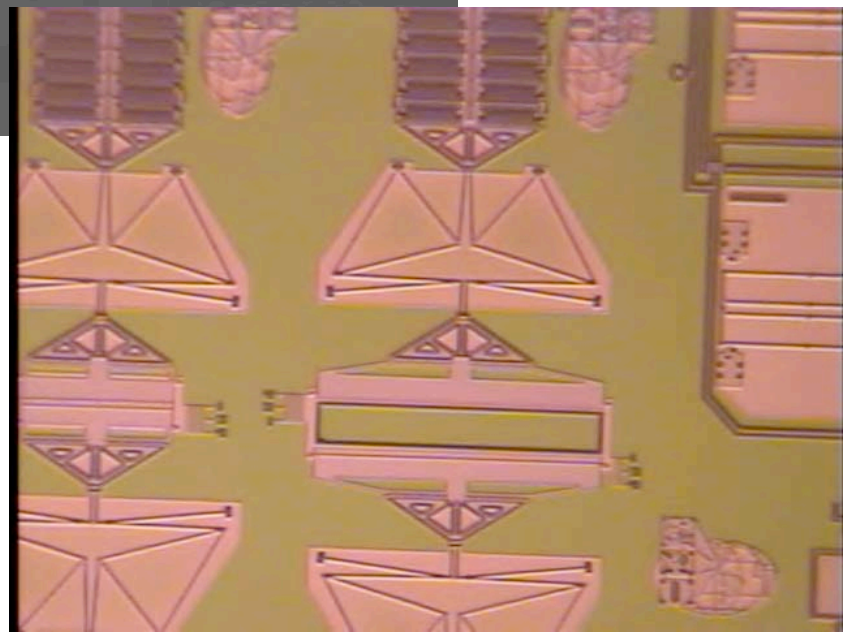


- Extremely sensitive to pressure (Q)
- Addition of specific absorbers measures constituents: $f \sim (k/m)^{1/2}$



Long Lifetimes Even in Vacuum





- "Barn Door" device
  - High force, small displacement motor
  - Force multiplier used to increase range of motion
- $>10^{10}$ cycles without degradation

High Pressure Testing

- Commercial test-pressure vessels to 50 bar
- Higher pressures achievable
- Open MEMs intrinsically highly pressure tolerant (>1000 bar)

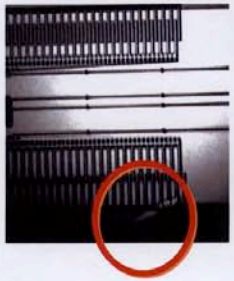
Outstanding Shock Survivability

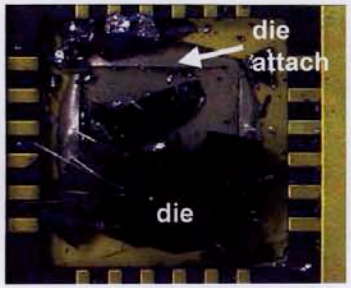
Environment: SHOCK Summary — Micromachines Are Extremely Robust

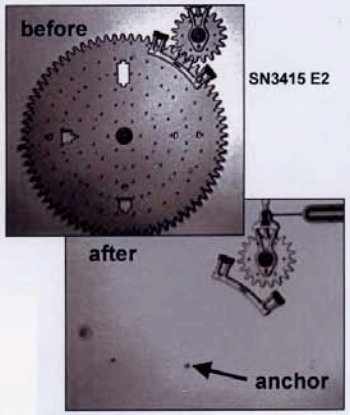
shock level:
G

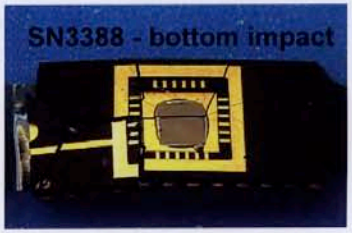
500 4000 10000 20000 40000

debris movement | die attach failure | structural damage | ceramic pkg. fracture









D. Tanner et.al., IRPS 2000

- working devices found out to 40 kG
- design/process modifications can allow survival beyond 20,000 G

Sandia National Laboratories

Attributes of MEMS Devices

- Very small mass and size
- Very low power
- Functionality over broad pressure and temperature regimes
  - Vacuum to >1000 bar
  - Temperatures from 10s to >1000 K
- High impact, shock, and vibration tolerance
- Intrinsically radiation-tolerant
- Very high reliability (>10^{10} cycles)
- Repeatability and Testability
- Redundancy
- Relatively low cost

Applicability for Planetary Probes

Broad array of possible applications for probe measurements and other subsystems

Many Advantages for Probes

- Attributes of MEMS-based sensors/subsystems ideal for rigors of launch, space, and many planetary probes environments
- Allows integrated miniaturized instrumentation, multiple measurements, redundancy, and integrated electronics
- Miniaturized probes require much smaller power sources, mechanical structure, parachutes (may not be required), and heat shields than their full-scale siblings

Some Existing MEMS Sensors

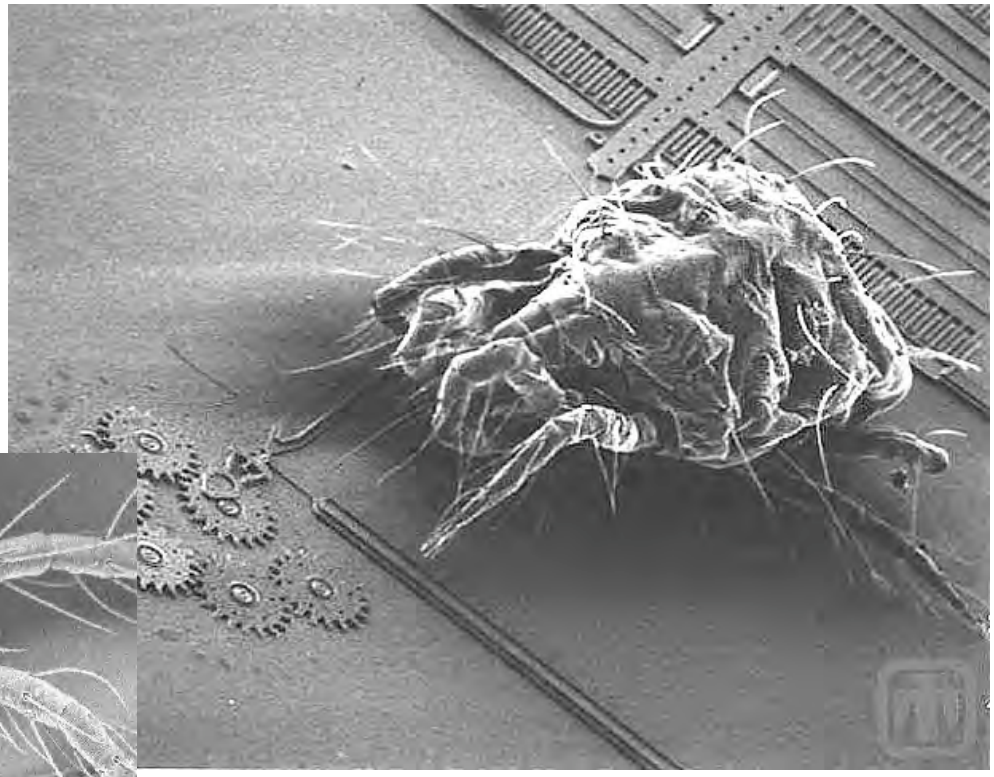
- Pressure
- Temperature
- Acceleration
- Magnetic fields
- Wind / Flows
- Humidity
- Targeted chemical composition of gasses
- Variety of other parameters
- New applications constantly being developed
  - Driven by huge commercial investments

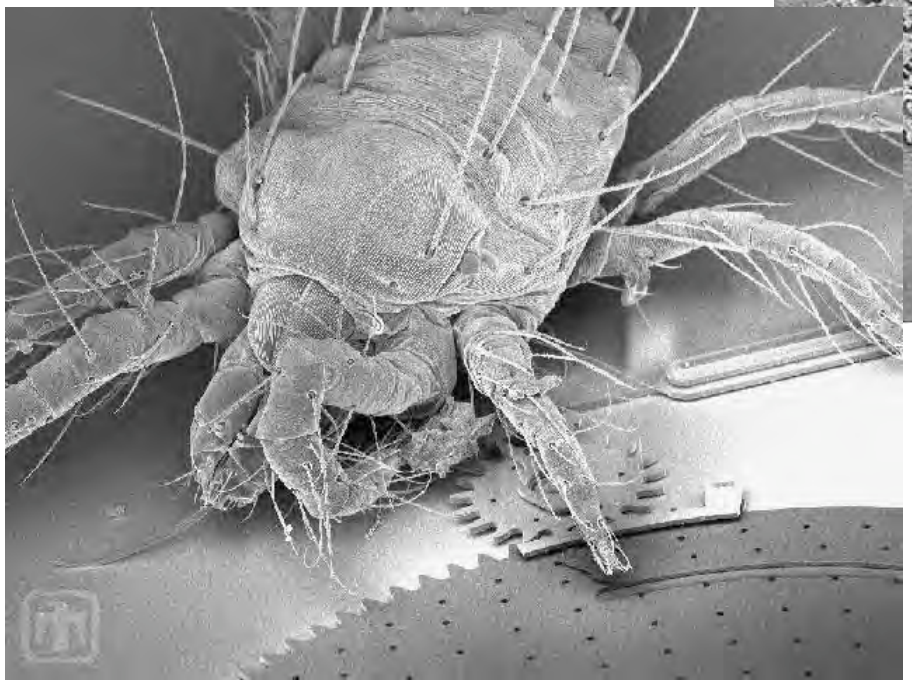
Many Potential Power Sources

- Normal external - very low power requirements
- Micro-batteries
- MEMS-scale sources – can be integrated
  - Thermal – uses temperate differences
  - Vibration/motion scavenging – electromechanical
    - Inductive/Piezoelectric/Capacitive
  - Solar cells
  - Generators/turbines
  - Fuel cells

Also Great for Detecting Life!!!

Dust Mites





OK, not like this but maybe through other measurements

Conclusions

- Introduced basic principles of MEMS/MEMPPs
- Applicable to certain focused observations which can cover a broad array of planetary atmospheric and surface probes within very small packages and limited resources
- MEMPPs provide several significant advantages
  - Integrated packages of intrinsically robust instrumentation and subsystems
  - Much smaller size, mass, and power requirements
  - May enable large numbers of distributed probes